P2.13 ASSIMILATION OF CLOUD-TOP PRESSURE DERIVED FROM GOES SOUNDER DATA INTO MAPS/RUC

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1. INTRODUCTION

FSL has developed and begun real-time testing of a preliminary assimilation technique using the cloud-top product from NESDIS (based on the GOES sounder). This product, available hourly, is being assimilated into a test version of THE Mesoscale Analysis and Prediction System (MAPS), which also runs as the operational Rapid Update Cycle (RUC) at NCEP. MAPS/RUC provides explicit forecasts of mixing ratio for 5 hydrometeor types -- cloud water, rain water, ice, snow, and graupel. Thus, background vertical profiles of these hydrometeors, as well as water vapor, are available each hour from the previous 1-h forecast as part of the 1-h MAPS/RUC assimilation cycle (Benjamin et al., 1999). In the assimilation technique, these hydrometeor and water vapor profiles are adjusted at each grid point where GOES cloud-top pressure data are available. Clouds may be built or cleared or vertically clipped depending on the difference between the background hydrometeor cloud top and the GOES cloud-top pressure.

The GOES-derived cloud product used in the experiments is available hourly from NESDIS/CIMSS in Madison, Wisconsin (Menzel et al., 1998). The product covers about two-thirds of the MAPS domain (using both GOES-8 and GOES-10 data). The spot-to-spot distance of sounder data is about 10 km but the 3x3 pixel data processing results in data resolution of about 30 km. Then the GOES-derived cloud product is mapped onto MAPS grid points by taking the nearest GOES 30-km value when more than one is available within a MAPS grid box. In an earlier study, we compared the GOES cloud product and MAPS/RUC-predicted cloud-top with very accurate data from the cloud-profiling radar at the ARM/CART central site in northern Oklahoma, U. S. (Kim et al. 1998). This comparison showed good accuracy for the GOES product. Nevertheless, the product errors must be well understood for optimal assimilation. The goal of this study is to demonstrate the impact of GOES-derived cloud-top in real-time MAPS/RUC moisture variable.

2. TECHNIQUE DESCRIPTION

The assimilation of GOES-derived cloud-top pressure into MAPS includes both cloud clearing and building. For cloud clearing, any hydrometeors in the first guess above the GOES cloud-top (or whole column) are removed and relative humidity is set in cleared grid volumes to 50%. For cloud building, hydrometeor mixing ratios (proportioned between water and ice according to a temperature-dependent saturation mixing ratio curve) are set in a layer below the GOES cloud-top pressure. The water vapor mixing ratio is adjusted such that the relative humidity is 100%. At the current time, we require that the GOES cloud fraction exceed 0.8 before any cloud building occurs. Forecast clouds are only cleared when this fraction is below 0.1. These adjustments are carried at all grid points within coverage of GOES-8 and 10. Then the adjusted fields are used to initialize the next forecast in the assimilation cycle.

3. TESTS IN PARALLEL MAPS CYCLES

A parallel MAPS cycle with GOES cloud-top assimilation was run alongside a control cycle without the cloud analysis for a period of 39 days. For this test period, verification statistics such as bias, standard deviation, and correlation coefficient were computed.

The correlation coefficient verification in Fig. 1 (parallel run) and Fig. 2 (control run) show a clear improvement in cloud forecasts from the parallel run with cloud assimilation, especially for the 1-h, 3-h and 6-h forecasts. The impact of cloud assimilation decreases with forecast duration, as expected, but some improvement is still apparent even in most 12-h forecasts. This pattern is typical of the test period. The control run (Fig. 2) shows virtually no difference between 1-h and 3-h forecasts; occasionally longer forecast projections result in better statistics than those of shorter forecast (e.g., Julian day 203). In the parallel cycle, there is also indication of a diurnal cycle in the effectiveness of the cloud assimilation. The 1-h forecasts show higher correlation coefficients with GOES-derived cloud tops during nighttime hours, and lower values during the daytime. It is hypothesized that convective clouds are more active and rapidly growing and decaying during daytime, resulting in this behavior. Future analysis of persistence forecasts of cloud-top pressure will be performed to investigate this hypothesis.

The verification of 3-h relative humidity forecasts against rawinsondes is shown in Fig. 3. The forecasts are initialized at 0900 and 2100 UTC and verified for the period 1 July through 8 August 1999. These statistics (standard deviation of forecast-minus-rawinsonde value) show positive impact on relative humidity forecasts from GOES cloud-top assimilation, up to 1.5% RH at 300 mb. At 12 h (not shown), this positive impact is reduced (0.5% at 300 mb) but still present.

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4. FURTHER INVESTIGATION OF IMPACT

We have also developed an assimilation impact analysis package to better understand why positive impact occurs and what its spatial distribution is. First, we made a 2x2 contingency table of clear vs. cloud and model forecast vs. satellite product (see Table 1). Then, the histogram (equivalently, density) of satellite cloud-top minus forecast cloud-top was obtained for each element in the 2x2 contingency table (see Fig. 4). Each histogram is subdivided into identifiable groups by an automatic adaptive classification method (Kim and Nychka, 1998), and the spatial distribution in each group (Fig. 5).

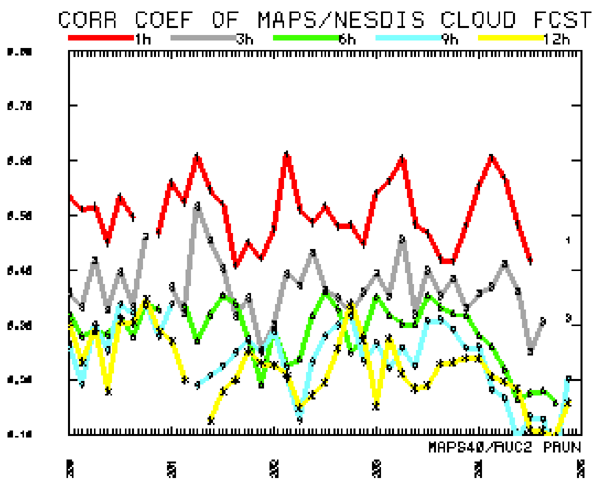


Figure 1. Time-series of correlation coefficients of predicted cloud-top pressures from parallel run with cloud analyses and GOES-derived values. The statistics every 3 h show predictions of 1, 3, 6, 9, and 12 h for initial times starting at 0000 UTC 19 July 1999 (Julian day of 200) for five days. The vertical axis extends from 0.1 to 0.8 with a 0.1 interval.

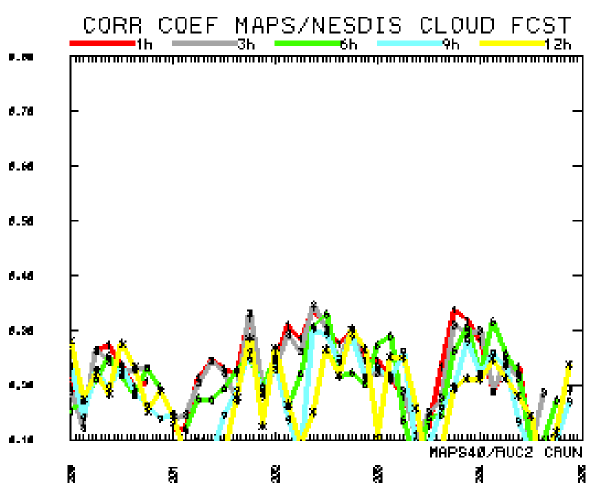


Fig. 2 The same as Fig.1 except for control run forecasts.

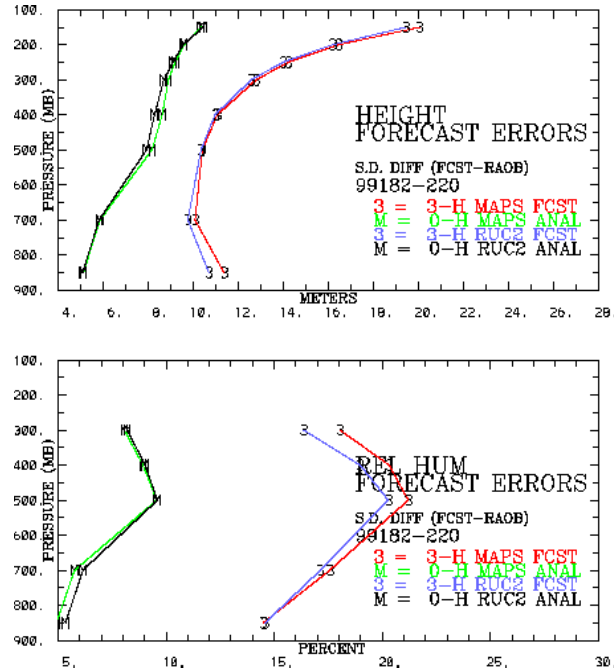


Fig. 3 Comparison of 3-h MAPS height and RH forecast error standard deviations verified against rawinsonde observations for 39 days from 1 July through 8 August 1999. Results are shown for the control run (no cloud assimilation - red) and the parallel run (with cloud assimilation - purple and labeled "RUC2")

Figure 4 shows histograms for 3-h forecasts vs. GOES-derived cloud-top pressures for the valid time of 1800 UTC 14 August 1999. The MAPS forecasts are the 3-h forecasts initialized at 1500 UTC from the control and parallel cycles, without and with cloud assimilation respectively, at earlier times. The pressure reported for GOES in the event of clear conditions is 1013 hPa, whereas the reported MAPS value is the surface pressure. Thus, Fig. 4a resembles a distribution of the MAPS surface pressure difference from 1013 hPa. The primary mode in Fig. 4b (when MAPS fails to predict observed clouds) represents prediction errors of low-level clouds, and the secondary mode corresponds to failure to predict upper-level clouds. Fig. 4c (MAPS predicts cloud, GOES clear) has implications for improving the MAPS model cloud microphysics. The blue bars at the far right indicate rapid accumulation of hydrometeors at high levels, e.g., above 200 hPa. In Fig. 4d both GOES and MAPS forecasts have clouds at some level, and there is a higher concentration of blue bars near 0 hPa (cloud forecast at correct level), indicating that the parallel run with cloud assimilation has a closer agreement to the cloud-top observations than the control run. Also, the size of the secondary mode in the parallel run is smaller than that of the control run, indicating clearing of high clouds is at least partially effective.

The automatic adaptive classification method was applied to the parallel run results when observed clouds were not forecast (Fig. 4b) as an example. The method divides these events into two groups separated at the value of -504 hPa (632 grid points in the first group, 2448 in the second group, out of total 3080 - see Table 1). The geographic distribution of grid points in each group are shown in Fig. 5. Fig. 5a (unforecast high clouds) includes an area over Kansas. Further analysis showed that the cloud fraction in this same area 3 h earlier was less than 0.8, so the cloud analysis did not build these clouds (indicating further refinements are needed for lower cloud fraction). Thus, this was more of an initialization (or verification) issue rather than a forecast model error. The primary area for unforecast low-level clouds (Fig. 5b) was off the California coast; much of this problem is attributable to an erroneous height assignment in the GOES-derived product that NESDIS is now fixing. These subdivided groups in Fig.4.b did not show any significant spatially coherent pattern with subdivided groups in Fig.4.c.

The contingency table (Table 1) for this forecast shows that the cloud analysis effectively reduces unobserved clouds but also results in a slight increase in the number of grid points where the the forecast is clear but clouds are shown by GOES.

		GOES		
		Clear	**Cloud**	**Total**
MAPS FCST	**Clear**	**3716 (3039)**	**3080 (2867)**	**6796**
	Cloud	**798 (1475)**	**4034 (4247)**	**4832**
	Total	**4514**	**7114**	**12628**

Table 1. Contingency table of GOES-derived vs. forecast cloud at MAPS grid points for parallel run shown in Fig. 4 and control run (in parentheses).

a)

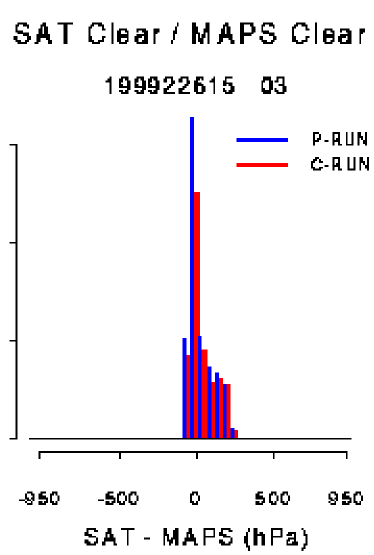
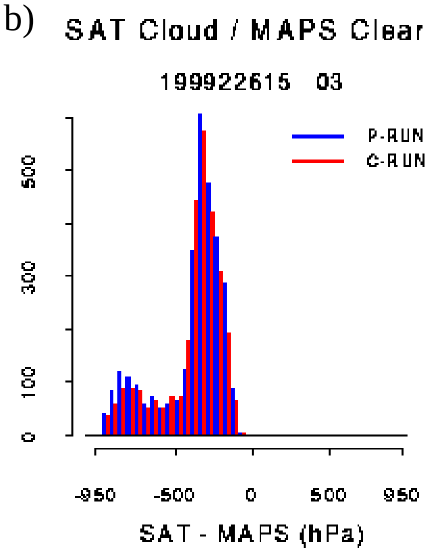
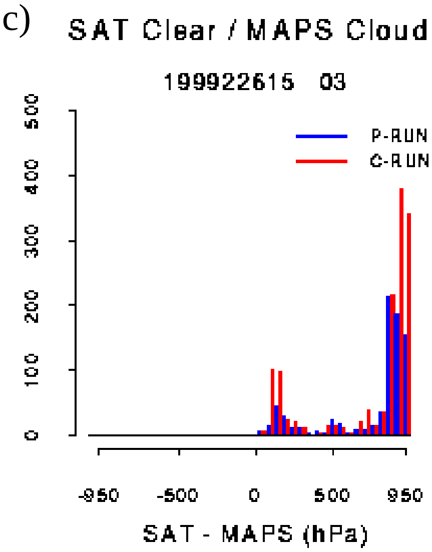


Figure 4. Histograms of numbers of grid ponts for various ranges of GOES cloud minus MAPS predicted cloud-top pressure (3 h forecast) valid at 1800 UTC 14 August 1999. Bars from parallel (blue, or dark) and control (red, or grey) runs are plotted for the following cases: a) GOES and MAPS forecast both showed no clouds, b) MAPS failed to predict observed clouds, c) MAPS predicted unobserved (by GOES) clouds, d) cloud cover was accurately predicted by MAPS but not necessarily with the same cloud-top pressure as indicated by GOES.

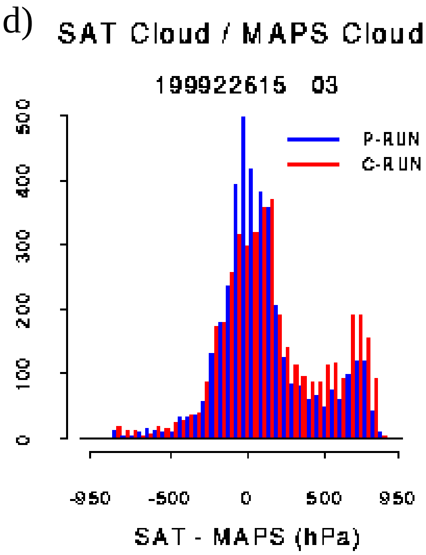
b)



c)



d)



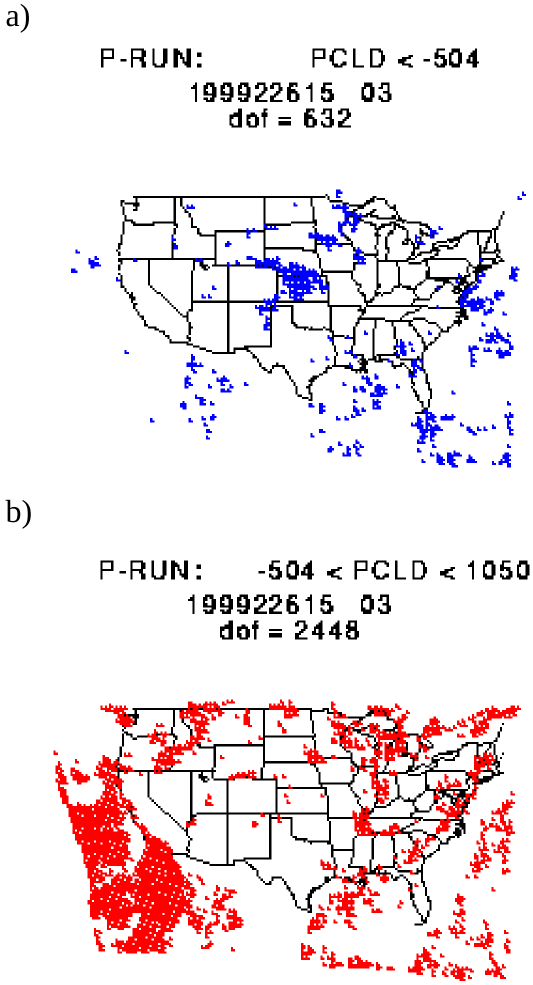


Fig. 5 Spatial distribution of grid points subdivided by a classification technique into a) unforecast high clouds, and b) unforecast low clouds. For MAPS 3 h forecast valid at 1800 UTC 14 August 1999 compared to GOES cloud-top pressure valid at same time.

5. SUMMARY

A preliminary cloud analysis technique for the RUC/MAPS system has been developed and incorporated into a test parallel 1-h assimilation cycle. A cycle with hourly assimilation of GOES cloud-top pressure (along with other observations) was run in parallel with a control cycle without GOES cloud for a 39-day period. Verification results showed a strong positive impact from the GOES cloud assimilation on subsequent cloud-top forecasts for 1-h and 3-h forecasts, and a weaker positive impact out to 12 h. The effect of the GOES cloud assimilation on 3-h MAPS relative humidity forecasts was also found to be weakly positive.

The nature of cloud forecast errors in the control and parallel cycles was further examined with histograms of cloud-top pressure differences, contingency tables for MAPS/GOES and clear/cloudy conditions, and spatial maps from an automatic classification technique for determining dominant modes in situations where MAPS failed to predict observed clouds. Examples of these techniques were shown for a specific case, which showed remaining problems with the proper use of GOES cloud fraction and the prevention of over-clearing from GOES.

We note that in the case examined from August 1999, the number of cloudy grid points (7114) was somewhat larger than the number of clear points (4514, Table 1). This proportion, although from only one case, indicates that cloud clearing alone certainly significantly underutilizes the GOES cloud product for NWP initialization. Therefore, it is desirable to unify the treatment of both cloudy and clear columns in a single initialization procedure. Our results and experience also confirm the need to understand errors or ambiguities in the GOES cloud product that sometimes occur in the event of low-level cloud or semitransparent cloud.

6. ACKNOWLEDGMENTS

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